BNL – 68170
Informal Report

VISA Undulator Re-Alignment Using An Optical Monitoring System

A. Tremaine and A. Murokh
University of California
Los Angeles, CA 90095

X.J. Wang
National Synchrotron Light Source
Brookhaven National Laboratory
Upton, NY 11973, USA

January 2001

National Synchrotron Light Source

Brookhaven National Laboratory
Operated by
Brookhaven Science Associates
Upton, NY 11973

Under Contract with the United States Department of Energy
Contract Number DE-AC02-98CH10886

DISCLAIMER

VISA Undulator Re-Alignment using an Optical Monitoring System

A. Tremaine, A. Murokh
University of California, Los Angeles, 90095

X.J. Wang
Brookhaven National Laboratory, 11973

Abstract

The VISA experiment is designed to reach and study saturation in a high gain 800nm SASE FEL at the Brookhaven Accelerator Test Facility (ATF). To do this, the undulator must be aligned at first to within 20μm with use of a laser interferometric system. Once aligned, any small movements from the aligned position will greatly detriment the SASE FEL performance [1] thus making continuous monitoring of the undulator position necessary. This is quite a complicated task since the 4m undulator is made up of four 1m sections enclosed in a vacuum chamber. We have developed an in situ optical system to monitor the undulator position with an accuracy better than 10 μm. In addition, we have demonstrated the accuracy of this system by bringing the grossly misaligned VISA undulator (~500μm in some locations) into alignment and attaining very high gain of the SASE FEL.

Introduction

To reach the alignment tolerances necessary for VISA, a laser interferometric system was developed [2]. The undulator is placed on a pulse wire bench [3] and the trajectory optimized [4]. After the trajectory optimization, the interferometer system was used to attain a mapping of tooling balls that are attached to the sides of the undulator. Once this was done for all 4 sections, the undulator was transferred to the experimental hall at the ATF where another interferometric alignment corresponding to the mapping done in the magnetic measurement lab was completed. After completion, the vacuum chamber is closed up and pumped down thus making interferometric alignment impossible since contact is needed with the tooling balls for this process [1]. The non-contact monitoring system implemented after assembly presented in this report includes survey targets, CCD cameras and telescope optics.

Setup

Before the chamber/undulator was assembled, survey targets used as fiducials were attached to both ends of each undulator section using Torr Seal as seen in Fig. 1. Fig. 1, for example, shows the end of Section 3 and the beginning of Section 4. (A Cohu CCD camera with telescope optics is used for this viewing and is shown in Fig. 2). Also shown in the figure is the distance from one fiducial line to the other specified by the survey target manufacturer. The reason for survey targets is so a calibration of distances can be done and a resolution per pixel calculated no matter what telescope system is set up for viewing. Targets placed on the top of each undulator section are used for horizontal monitoring and those placed on the sides are used for vertical as shown in Fig. 2.

Both ends of each undulator section had a target and corresponding camera/telescope system. Since the junction space between sections are only ~1mm (Fig. 1,3), only one camera was needed to observe two section ends (the rear of one section and the front of the next). For the very front of the undulator (front of Section 1) and the very rear (end of Section 4) monitoring would just show a single target without reference to anything else. Since we have 4 Sections (3 junctions), 5 monitoring systems are needed for horizontal observation and 5 are needed for vertical.

The VISA undulator once under vacuum has the capability for horizontal and vertical adjustments. Each undulator section is supported by two translation stages giving a total of 8 stages in which to horizontally move the undulator while under vacuum. Also, the undulator and vacuum tank itself are isolated from one another through a bellows [5]. A movement in the undulator causes no effect on the tank placement. Likewise, tank movements, particularly during pumpdown, have no effect on the undulator position.

A picture of the camera with optics, vacuum chamber and undulator are shown in Fig. 2 and Fig. 3. The resolution obtained here (Fig. 1) is about 5μm/pixel. The resolution chosen gives us confidence in 10μm movements and also allows a field of view of the undulator of well over 1mm. It is reasonable to believe and has been tested outside of our experimental setup that resolutions of 2μm/pixel is straightforward to attain for these types of setups. One must note, the higher the resolution the closer the adjoining sections must be (see Fig. 1). Also, higher monitoring resolution is more susceptible to vibrations. We found that having the air conditioner on during monitoring testing gave vibrations of 3 pixels at one of the monitors.

We noted a slow drift in the system over the course of 24 hours. As seen in Fig. 2, the camera supports could be more structurally sound and the drift noticed at best was about 10μm/24 hours. It is reasonable to think a better mounting system could be developed and the slow drift problem eased. This problem is o.k. for the monitors looking at the junctions because it is the relative position of the junctions to each other which is important. For the beginning of Section 1 and the end of Section 4 there is no reference and drift of the camera would show up as motion in the undulator since the fiducial pixel position would have changed.

Undulator Correction

The VISA system, after an initial interferometric alignment, pumpdown and running beam showed no signs of the high gain performance predicted. After careful study a systematic error was found in the interferometric alignment routine of transferring the mapping done on the pulse wire bench to the ATF. Once the problem was found, further study illuminated the correct position of the undulator and an offset of the current position to the correct was calculated. Figure 4 shows the magnitude of these calculated horizontal offsets with the maximum misplacement being over .5mm. As stated above, without the precision alignment of the 4 segments to within 25μm, SASE performance is greatly reduced [1]. There were errors in the vertical, but they were within the budget allowed and so no correction in this dimension was needed. To the extent to which our undulator was misaligned, attaining high gain was hopeless.

The undulator was horizontally moved by the magnitudes given in Fig.4. Remember the movements were done while the system was under vacuum and a laser interferometric alignment is impossible. There was slight coupling between the sections due to the fact that the undulator sections are pulled longitudinally together by springs. For example, as the beginning of Section 3 was moved, we would observe motion in the end of Section 2. During any movement of the undulator all monitors where on and the positions of the all the undulator sections where noted. Fig.1 shows the before and after movement of the junction between Sections 3 and Sections 4.

Once the movements were completed and belief that the undulator was straight beam was run to the VISA system. Exactly two months after this movement correction, high gain was attained and strong evidence of saturation observed [6]. This indicates that the movements described above were indeed to within the 4 section alignment tolerances and the undulator monitoring performed to the resolution described above.

Discussion

One should point out that this system could have and can be easily used in the precision alignments of undulator segments as an independent check of the laser interferometer. If on the pulse wire bench pictures were taken of the junction fiducials like in Fig. 1, then the interferometric alignment of the undulator would be quite straightforward. Using the telescope optics, the undulator fiducials should be the same offset as measured on the pulse wire bench. It should be noted that an absolute alignment using this system can not be done. The laser interferometer has the laser as a reference line and this monitoring system has no such luxury.

In addition, it is possible to have all three dimensions monitored with just one camera. More advance and expensive telescoping systems not only can tell translations to the accuracy stated above, but also depth to <1μm. For our system, only 1 of these advanced telescoping monitors would be needed for both horizontal and vertical movements. This would require only a total of 5 monitors for our system unlike the 10 needed.

References

[1] P. Emma *et al*., Proceedings of the 20th International FEL Conference (FEL98), Williamsburg, Va., USA, 1198, SLAC-PB-7913

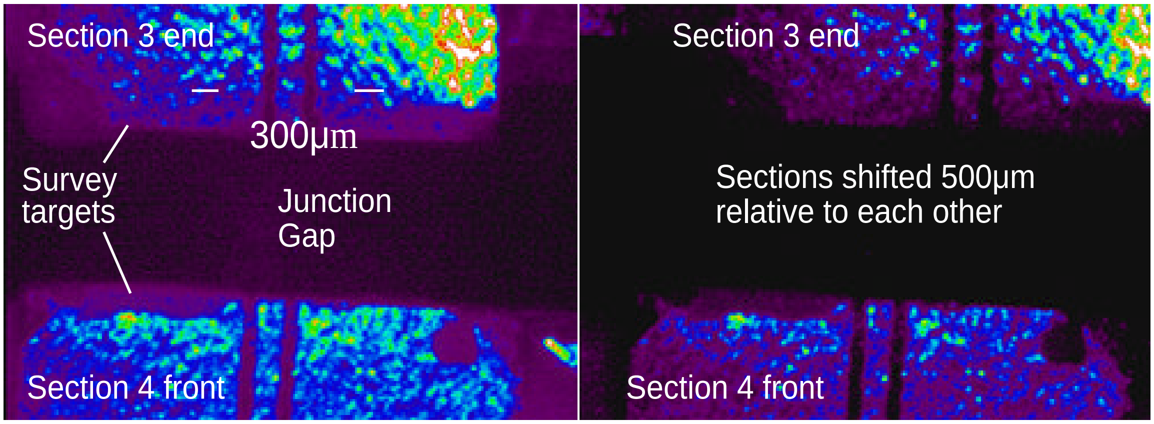
[2] R. Ruland *et al*., Proceedings 1999 Particle Accelerator Conference, New York, New York

[3] R. Warren and C. Fortgang, Nucl. Inst. & Methods A341 (1994) p. 444

[4] G. Rakowsky *et al.,* Proceedings 1999 Particle Accelerator Conference, New York, New York

[5] R. Carr *et al.,* submitted to Physical Review

[6] A. Tremaine *et al*., to be published in the Proceedings of the 2001 Particle Accelerator Conference, Chicago, Ill.



1a. Before move 1b. After move

Figure 1. Fiducials captured through monitoring system before and after the horizontal movements of the undulator. Shown is the rear of Section 3 and the front of Section 4. The resolution is ~5μm/pixel and it is easily and accurately seen the movements imposed upon the undulator.

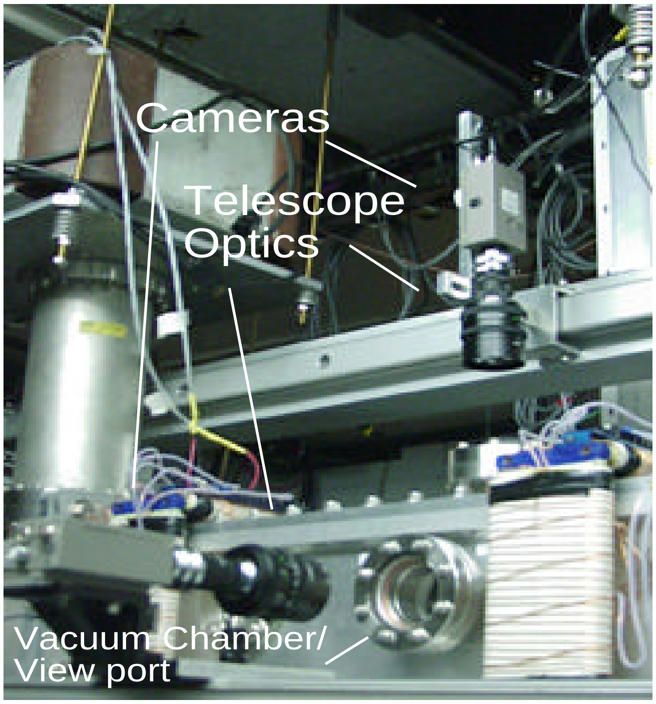


Figure 2. Monitoring Setup. Cameras are used for both horizontal and vertical monitoring of the undulator. Since undulator is in a vacuum chamber, cameras using telescoping optics monitor the undulator through viewports on the chamber.

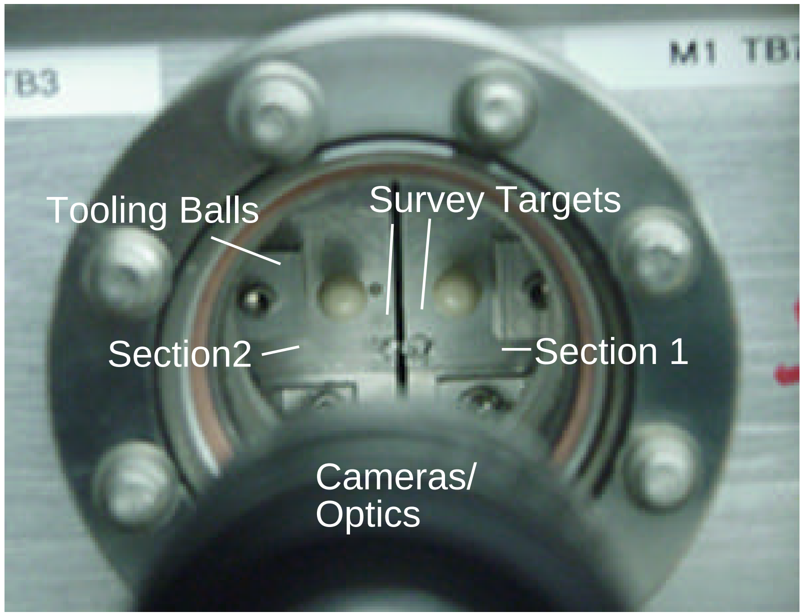


Figure 3. Camera and optics looking through a viewport onto the undulator junction between Sections 1&2. Seen are the tooling balls used in the laser interferometric alignment and the survey targets used in our monitor. Shown is the end of undulator Section 1 and the beginning of undulator Section 2. The space between the sections is ~1mm.

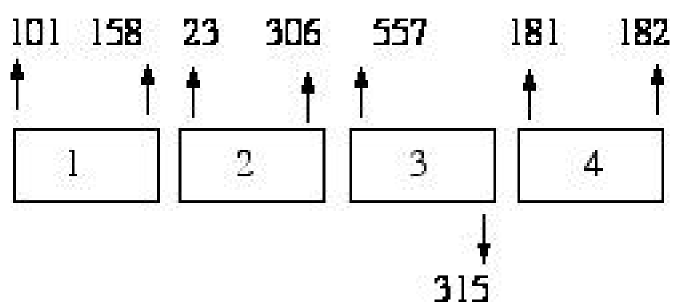


Figure 4. VISA horizontal misalignment in μm. These are the horizontal movements made in all four sections using the monitoring system.